Novel synthesis technique for high efficiency conversion of source gas to diamond

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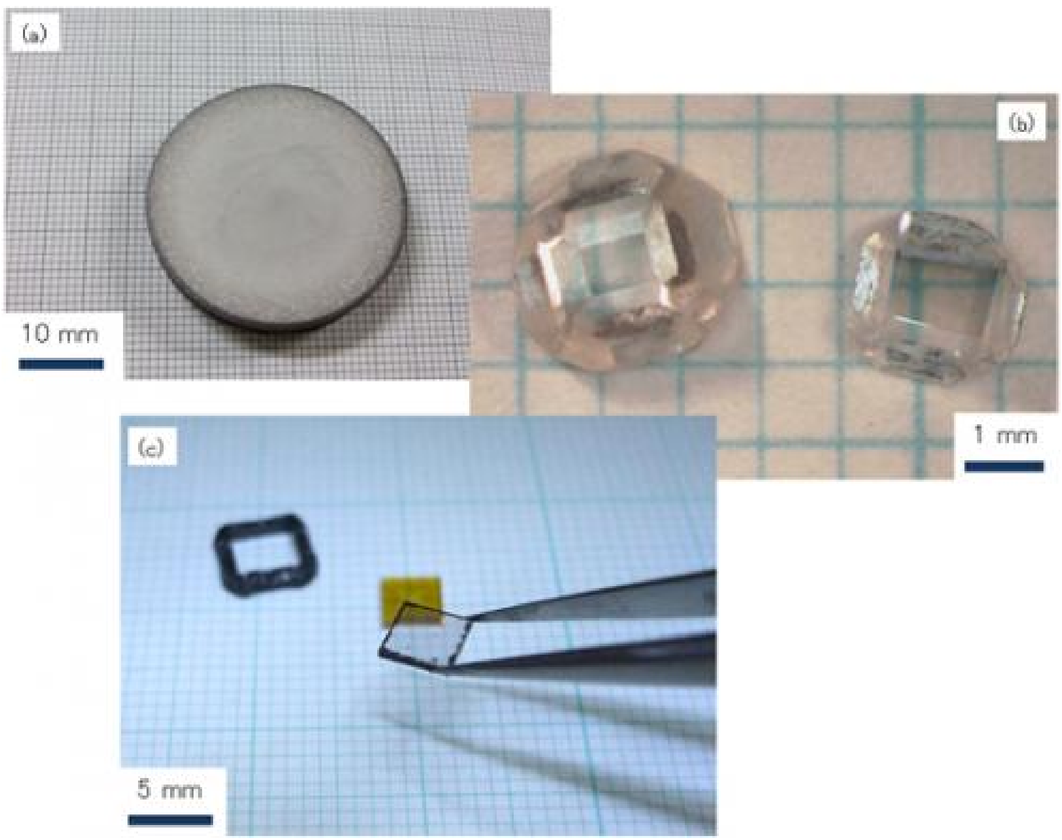

Isotopically-enriched diamond crystals obtained by the new synthesis technique. (a) CVD polycrystalline diamond: Diamond with a thickness of 0.5mm was synthesized over the entire surface of a molybdenum disk (diameter: 30mm). (b) HPHT single crystal diamond: An attempt was made to further improve the isotopic ratio. (c) CVD single crystal diamond: High purity, high isotopic ratio single crystal diamond was synthesized on a widely-utilized single crystal substrate containing nitrogen (yellow), and this CVD single crystal and the substrate were later separated.

A research group from the National Institute for Materials Science, developed a novel synthesis technique which dramatically increases the source material utilization rate in the diamond chemical vapor deposition (CVD). The group applied this new technique to synthesis of diamond crystals which were isotopically-enriched with mass number 12 carbon (^{12}C), and succeeded in synthesizing a diamond bulk single crystal with the world's highest ^{12}C isotopic ratio.

When high purity diamond is synthesized by the CVD process, methane gas is generally used as the source gas. Normally, at most 1% of the supplied methane gas is converted to diamond, and 99% or more of the methane gas is emitted to the atmosphere before utilizing for diamond synthesis. Due to this low material utilization rate, it had been difficult from the viewpoint of cost to use expensive gas in bulk crystal synthesis, as the conventional process consumed a large amount of source gas. In the newly-developed CVD diamond synthesis technique, the utilization rate of the methane source gas was dramatically improved by supplying the gas under conditions greatly different from those in the conventional process. As a result, an extremely high gas utilization rate of 80% was realized when synthesizing polycrystalline diamond.

The development of this CVD synthesis technique with a high gas utilization rate makes it possible to synthesize diamond using extremely expensive isotopically-enriched methane as the source gas. As a result, the NIMS group succeeded in obtaining diamond bulk single crystals with the world's highest ^{12}C isotopic ratio of 99.998% (isotopic ratio of ^{13}C: 0.002%). Single crystal diamond with a ^{12}C isotopic ratio of 99.995% was then obtained by using the polycrystalline diamond produced by this technique (isotopic ratio of ^{12}C: 99.998%) as a solid source material for diamond synthesis by the high pressure/high temperature (HPHT) process, which requires a solid source material. Because ^{12}C enriched methane gas, etc. is generally supplied as a source gas, this CVD technique, which greatly improves the methane source gas utilization rate, is essential for obtaining ^{12}C solid carbon material for use in HPHT synthesis.

Various applications, such as use in high performance heat sinks, etc., are expected with ^{12}C enriched diamond, which has higher thermal conductivity than diamond having a natural ^{12}C ratio of 98.9% (13C: 1.1%). Moreover, as it is known that the coherent time of electronic spin becomes longer in ^{12}C enriched diamond crystals, accelerated development aiming at high performance quantum information communication devices using diamond is also expected.

These research results were announced in the online bulletin of the scientific journal *Applied Physics Express* on April 15, 2013 (Japan time).

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